FOOD PACKAGING
FST - 605

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UNIT I (Lectures 4)

Food Packaging

Lecture – 1

- Introduction to Food Packaging
- Active and intelligent packaging
- Active packaging techniques
- Intelligent packaging techniques

Introduction to Food Packaging

- As long as civilization has existed, packaging and storage of food has been integral to survival.
- Glass, wood and earthen pots have been used for thousands of years and over the last two hundred years, steel and tin coated steel have been used not only for containing food but also to preserve it.
- Packaging which used to be a mere necessity few decades back has now turned into an art and science.
- It surrounds, enhances and protects the goods we buy, from processing and manufacturing, through handling and storage, to the final consumer.
- Packaging is important to maintain the basic attributes of food (temperature, color, taste, texture, etc.) maintaining food safety is an important function of packaging.
- Without packaging, materials handling would be a messy, inefficient and costly exercise.

Definition of Packaging

- The Packaging Institute International (PII) defines packaging as the "enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other container form to perform one or more of the following functions: containment, protection, preservation, communication, utility and performance".

- If the device or container performs one or more of these functions, it is considered a package.

Package, Packaging, Packing

- It is important to distinguish between the words "package," "packaging" and "packing."

- “Package” is the physical entity that contains the product.

- “Packaging” is a discipline, a system of preparing goods for transport, distribution, storage, retailing and end-use, a means of ensuring safe delivery to the ultimate consumer in sound condition at optimum cost, and a techno-commercial function aimed at optimizing the costs of delivery while maximizing sales.

- “Packing" can be defined as the enclosing of an individual item (or several items) in a package or container.

Active Packaging

- Active packaging is accurately defined as “packaging in which subsidiary constituents have been deliberately included in or on either the packaging material or the package headspace to enhance the performance of the package system” (Robertson, 2006).

- Active packaging is an extension of the protection function of a package and is commonly used to protect against oxygen and moisture.

- Active packaging refers to the incorporation of certain additives into packaging film or within packaging containers with the aim of maintaining and extending product shelf life [Day, 1989].

- Active packaging, however, allows packages to interact with food and the environment and play a dynamic role in food preservation [Brody et al., 2001; Lopez- -Rubio et al., 2004].

Selected examples of active packaging systems

Active packaging	System mechanisms food	Applications
Oxygen scavengers	Iron based, Metal/acid Nylon MXD6, Metal (e.g. platinum) catalyst Ascorbate/metallic salts Enzyme based	Bread, cakes, cooked rice, biscuits, pizza, pasta, cheese, cured meats and fish, coffee, snack foods, dried foods and beverages
Carbon dioxide scavengers/emitters	Iron oxide/calcium hydroxide Ferrous carbonate/metal halide Calcium oxide/activated charcoal Ascorbate/sodium bicarbonate	Coffee, fresh meats and fish, nuts and other snack food products and sponge cakes
Ethylene scavengers	Potassium permanganate Activated carbon Activated clays/zeolites	Fruit, vegetables and other horticultural products
Preservative releasers	Organic acids Silver zeolite Spice and herb extracts BHA/BHT antioxidants Vitamin E antioxidant Chlorine dioxide/sulphur dioxide	Cereals, meats, fish, bread, cheese, snack foods, fruit and vegetables

Intelligent Packaging

- Intelligent packaging could be defined; as a packaging system that is capable of carrying out intelligent functions (such as sensing, detecting, tracing, recording and communicating) to facilitate decision making to extend shelf life, improve quality, enhance safety, provide information, and warn about possible problems.
- Packaging that contains an external or internal indicator to provide information about aspects of the history of the package and/or the quality of the food.
- Intelligent packaging systems possess diagnostic and indicator functions for:
    - Gases/leaks
    - Time/temperature
    - Freshness

  Shops and consumers can therefore easily see from the indicator whether a critical limit value has been exceeded.
- It is of two types:
    1. Measuring the condition of the package on the outside
    2. Measuring directly the quality of the food product inside the packaging

Active Packaging Techniques

- Active packaging employs a packaging material that interacts with the internal gas environment to extend the shelf life of a food.
- Such new technologies continuously modify the gas environment (and may interact with the surface of the food) by removing gases from or adding gases to the headspace inside a package.

Ethylene Scavenging

- A chemical reagent, incorporated into the packaging film, traps the ethylene produced by ripening fruit or vegetables.
- The reaction is irreversible and small quantities of the scavenger are required to remove ethylene at the concentrations at which it is produced.
- A feature of this system is its pink colour, which can be used as an indicator of the extent of reaction and shows when the scavenger is used up.

Oxygen Scavenging

- The presence of oxygen in food packages accelerates the spoilage of many foods.
- Oxygen can cause off-flavour development, colour change, nutrient loss and microbial attack.
- One of the most promising applications of oxygen scavenging systems in food packages is to control mold growth.

Active Packaging Techniques

Humidity Control

- Condensation or 'sweating' is a problem in many kinds of packaged fruit and vegetables.
- When the condensation wets the produce, nutrients leak into the water encouraging rapid mold growth.
- When the condensation inside packages is controlled, the food remains dry without drying out the product itself.
- Therefore sensitive fruits and vegetables are protected from contact with water. This helps to reduce growth of mold.

Carbon Dioxide Release

- High carbon dioxide levels are desirable in some food packages because they inhibit surface growth of micro organisms.
- Fresh meat, poultry, fish, cheeses and strawberries are foods, which can benefit from packaging in a high carbon dioxide atmosphere.
- Since carbon dioxide is more permeable through plastic films than is oxygen, carbon dioxide will need to be actively produced in some applications to maintain the desired atmosphere in the package.

Active Packaging Techniques

Ethanol

- Antimicrobial activity of ethanol (or common alcohol) is well known and it is used in medical and pharmaceutical applications.
- Ethanol has been shown to increase the shelf life of bread and other baked products when sprayed onto product surfaces prior to packaging.

Sulphur Dioxide

- Sulphur dioxide is primarily used to control meld growth in some fruits.
- Serious loss of table grapes can occur unless precautions are taken against mold growth.
- It is necessary to refrigerate grapes in combination with fumigation using low levels of sulphur dioxide.
- Fumigation can be conducted in the fruit cool stores as well as in the cartons.
- Carton fumigation consists of a combination of quick release and slow release systems, which emit small amounts of sulphur dioxide.

Other Developments

- Sachets containing iron powder and calcium hydroxide, which scavenge both oxygen and carbon dioxide. These sachets are used to extend the shelf life of ground coffee.
- Film containing microbial inhibitors other than those noted above. Other inhibitors being investigated include metal ions and salts of propionic acid.
- Specially fabricated films to absorb flavours and doors or, conversely, to release them into the package.

Intelligent Packaging Techniques

Indicators

Time-temperature indicator

- This indicator gives information on temperature and shows the variation and history in temperature.
- It is used as supplement to labelling in transportation or storage.
- If perishable food products are stored above the suitable storage temperature, a rapid microbial growth takes place. Time-temperature indicators (TTI) attached to the package surface is designed for integrate the cumulative time-temperature history of the package throughout the whole distribution chain, and therefore, gives indirect information on the product quality.
- The time-temperature history is visualised as a colour movement or colour change.

Oxygen indicator

- This indicator is giving information on leakage. A typical oxygen indicator consists of a redox-dye (such as methylene blue), an alkaline compound (such as sodium hydroxide) and a reducing compound (such as reducing sugars).
- Oxygen indicators have been recently described which based on oxidative enzymes. In addition to these main components, such as a solvent (water or an alcohol) and bulking agent (such as silica gel, polymers, cellulose materials, zeolite) compounds are added to the indicator.

Intelligent Packaging Techniques

Carbon dioxide indicator

- This indicator gives information on concentration of carbon dioxide in modified atmosphere packaging.
- The usage area of this indicator is controlled or modified atmosphere packaging.

Colour indicator

- This indicator gives information on temperature in food packaging.
- Food for microwave preparation is the usage area of this indicator.

Pathogen indicator

- This indicator gives information on microbiological status and it is used on meat, fish or poultry packaging.

Freshness indicators

- Freshness indicators indicate the microbial quality of the product by reacting to the metabolites produced in the growth of microorganisms.
- A specific indicator material has been developed for the detection of *E. coli* O157 enterotoxin and the possibility for applying the technology for the detection of other toxins is currently being explored.

Intelligent Packaging Techniques

Breakage indicator

- This indicator gives information on broken packaging and it is used on canned baby food packaging.

Leak Indicators

- A leak indicator gives information on the package integrity throughout the whole distribution chain which attached into the package.
- Exclusion of oxygen and high concentration of carbon dioxide improves the stability of the product as the growth of aerobic microorganisms is prevented for many perishable products.

Radio Frequency Identification Tags (RFID)

- Wireless data collection technology, uses electronic tags for storing data and identification of animals, objects or people.
- Tags attached to assets (pallets, cattle, packs, meat bins) to transmit information to a reader.
- Tags are could be classified into two categories; first one is passive tag which is cheap, simple, short-range, powered by energy from reader and the second one is active tag which is battery powered, longer range, more information (nutritional information, temperature, cooking instructions etc.).

Intelligent Packaging Techniques

Sensors

Intelligent sensors

- Devices used to locate, detect or quantify matter or energy, giving a signal for the detection of a chemical or physical property to which the device responds.

Most of devices contain two functional units:

- First one is receptor which is transformed chemical or physical information into a form of energy;
- Second one is transducer which is a device that transforms this energy into a useful analytical signal.

Bio-Sensors

- Compact analytical devices that detect, transmit and record information pertaining to biological reactions.
- Specific to a target analyte (such as; microbes, hormones, enzymes, antigens) is bio-receptor.

Gas Sensors

- Gas sensors are devices that respond quantitatively and reversibly to the presence of a gaseous analyte by changing the physical parameters of the sensor and are monitored by an external device.

Lecture – 2

- Current use of novel packaging techniques.
- Oxygen scavengers.
- Ethylene and other scavengers.
- Oxygen scavenging technology.

Current use of Novel Packaging Techniques

- Modern trend of retail practices and changing life style are the incentives for the evolution of novel and innovative packaging techniques without compromising food safety and quality characteristics (Dainelli et al., 2008)

- Rapid growth of novel packaging in food segment is contributed by the enormous use of packaged foods, rising need of prepared foods like use of microwave meals and growing use of smaller size food packages (Restuccia et al., 2010)

- The emerging changes in packaging industry will strengthen the economy by improving food safety, quality and minimizing product losses (Vanderroost et al., 2014).

Current use of Novel Packaging Techniques

Bioactive Packaging

- Bioactive packaging is the novel packaging technology that alters the package or coating in a way so as to have positive effect on consumer's health.
- Various techniques known to retain characteristic properties of biopolymers and employed in this novel packaging approach include; enzyme encapsulation, nano-encapsulation, microencapsulation and enzyme immobilization.
- Bioactive packaging has the potential to maintain bioactive substances in desired proportions until their controlled or fast diffusion within the packed food during it's storage or prior to it's consumption (Lopez-Rubio et al., 2006).
- Process of bioactive packaging technology is implemented via;
    - i) Utilization of biodegradable packaging materials for the release of functional or bioactive components,
    - ii) Encapsulating bio active ingredients into the foods or to the packaging materials,
    - iii) Introducing packaging materials exhibiting enzyme activity and capable of transforming some food components in order to deliver health benefits.
- The development of such packaging systems exerting health promotion effect involves the concept of marine oils, prebiotics, probiotics, encapsulated vitamins, phytochemicals, lactose free foods, bioavailable flavonoids and many more will boost the packaging industry in near future because of growing human health consciousness (Lagaron, 2005).

Current use of Novel Packaging Techniques

Innovative Packaging Technologies

Functional Barrier

- Functional barrier consists of one or more layers of food-contact materials.
- As, per definition the substances at the rear side of functional barrier will not, migrate in the food and thus will not have deleterious effects on human health nor will result in unacceptable changes in the composition and organoleptic properties.
- This implies that these intelligent and active substances do not arise the concern of safety issue and certain substances can be used at the rear side of functional barrier provided they migrate through the functional barrier below a certain detection limit.
- In case of articles for infants and other susceptible persons the prescribed limit of un authorized substances that might through the functional barrier should not exceed 0.01 mg per kg food.

Current use of Novel Packaging Techniques

High chemical barrier material innovations

- The quality of food can be maintained by preventing adsorption, desorption, diffusion of gases, liquids, penetration of other molecules such as oxygen, pressurized liquid or gas, and water vapor by the use of high-barrier packaging.

- The process of polymer blending, coating, lamination, or metallization is used to enhance the barrier property of packaging materials by combining the package materials with other high-barrier materials.

- The structural network of blend of packaging material with high barrier packaging material affects its permeability.

Current use of Novel Packaging Techniques

High chemical barrier material innovations

- Combining high-barrier materials on packaging material by the process of lamination or coating provides laminar structure, the permeability of which decreases linearly with the square thickness.

- Most commonly used blends are aluminum-metallization on PET, polyethylene terephthalate (PET) lamination on coextruded polypropylene/polyethylene, polymers with planar clay particles, mixture of beeswax in edible polymer as particulate system films and polyvinylidene chloride (PVdC) coating on oriented polypropylene (OPP) (Avella et al., 2005, Han et al., 2006).

- The innovative technique used to improve barrier property with commercial applicability include epoxy spray on PET bottles, transparent vacuum-deposited or plasma-deposited coating of silica oxide on PET films and composites of plastics with nanoparticles (Lopez-Rubio et al., 2004).

Current use of Novel Packaging Techniques

Intelligent Supply Chain

- In developing newer value added services, supply chain provides a provision of increasing efficiency by automating simple and valuable data flows.

- This intelligent supply chain can lay down flat form for value addition of fresh products.
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- In response to larger retailer mandates and compliance with regulatory bodies requirements a Spanish company ECOMOVISTAND developed an innovative and ecological packaging and transport unit, called MT, for the grocery supply chain, which can be used in the entire product cycle; that is, the MT serves
  (1) as packaging at the producer,
  (2) as transport unit,
  (3) as storage at warehouses, and
  (4) as display stand at the supermarket.

Current use of Novel Packaging Techniques

Interactions of Active/Intelligent Packaging with Supply Chain

- Special feature of supply chain is inclusion of several factors together for sound collaboration, coordination, and information exchanges between them for better efficiency and productivity (Choi et al., 2006).
- The major problem faced in transportation of boxes, containers, pallets and cases is lack of information and control on their status influenced by the actors in the supply chain.
- The world's largest container and pallet producing company encounters economical and logistics problems to provide on time service with a bounded quantity of pallets due to lack of information on where a pallet is and for how long it has been there.
- Thus, it does not seem astonishing why major retailers put thrust to come up with this lack of regulation and control by pushing suppliers towards the implementation of newer appropriate technologies.

Current use of Novel Packaging Techniques

Nanotechnologies in Food Packaging

- Nanotechnology has proven most promising innovative technique by introducing latest enhancements in food packaging by providing mechanical and barrier properties, detecting pathogens and introducing smart and active packaging keeping in consideration food quality and safety aspects.

- Presently, the nanotechnology that is playing part in the market is the nano-layer of aluminum that coats the interior of many snack food packages (Brody 2006).

- Nano-materials produced by the methods of solvent extraction/ evaporation, crystallization, self-assembly, layer-by-layer deposition, microbial synthesis, and biomass reactions are being tested for their applications in food packaging (Doyle 2006).

- Among the various nano-materials the most promising for food packaging is nano-composites.

Current use of Novel Packaging Techniques

Nano-composites

- Nano-composite packages for food have taken their place in the market and many are yet to be launched to contribute major portion in the future to food packaging.
- Nano-composite materials have played a vital role in improving the strength, barrier properties, antimicrobial properties, and stability to heat and cold (fundamental properties) of food packaging materials.
- The use of nano-composites for food packaging started in the year 1990s and use of montmorillonite clay as the nano-component has been used in a wide range of polymers such as polyethylene, nylon, polyvinyl chloride, and starch.
- The quantity of nano-clays used varied from 1% to 5% by weight and the nano-components used should have 1 dimension less than 1 nm wide.
- The high surface area of nano-composites is responsible for imparting unique properties when they are incorporated into packages.
- The transparent nano-composite coatings and plastic films known as Durethan, produced by Bayer contains clay nanoparticles dispersed throughout the plastic.

Current use of Novel Packaging Techniques

Nano-composites

- The nano-clay particles hinder the process of diffusion by acting as impermeable barrier and as a result of which shelf life and quality of foods is enhanced. The resulting food package is also strong, more heat-resistant and light weight, thereby reducing transportation costs.

- The problem of oxidation and flavor of beer in plastic bottles has also been tackled by the process of nanotechnology.

- Nanocor, a subsidiary of Amcol International Corp., have designed nano-composites that are employed in plastic beer bottles and can provide shelf life of 6 months.

- Use of nano-crystals incorporated in plastic bottles can extend the shelf life of beer by 18 months by preventing loss of carbon dioxide from and infusion of oxygen into the bottles.

Current use of Novel Packaging Techniques

Other Nanotechnologies

- The mechanical strength of food packaging materials can be improved by incorporation of carbon nanotubes of diameter in nanometers which are cylindrical in shape with antimicrobial properties.
- These carbon nanotubes in antimicrobial materials act as building blocks when they are single walled (Kang et al., 2007).
- In food packaging these has also been used in the form of nano-wheels to improve food packaging.
- The mechanical and barrier properties of plastics were improved by incorporation of self- aggregated inorganic alumina platelets in the shape of wagon-wheel (Mossinger et al., 2007).
- Nanotechnology has wider applications in the near future in the form of nano-sensors in food packages for detection of chemicals, bacteria, viruses, allergens, pathogens, and toxins in foods.

Current use of Novel Packaging Techniques

Other Nanotechnologies

- With the advent of nanotechnology nano-vesicles have been developed for detection of E. coli O157:H7, Salmonella spp., Listeria monocytogenes and Liposome nano-vesicles for detection of peanut allergen proteins.
- Further, a Nano-Bioluminescence detection spray has been devised that contains an engineered luminescent protein capable of binding to the microbial surface (Salmonella and E. coli) (Joseph and Morrison 2006).
- Recently, nano-components are being integrated in ultra-thin polymer substrates for RFID chips with biosensors that are capable of detecting foodborne pathogens or sense the moisture or temperature of a product (Nachay 2007).
- The most striking advancement of this technology is development of electronic tongue nano-sensors which can be to used to stimulate color changes in food packages in order to provide indications to consumers when food is spoiled and can also detect substances in parts per trillion (Univ. of Pennsylvania 2005)

Oxygen Scavengers

- Also known as Oxygen Absorbers.
- Oxygen can turn fats rancid, cause favor deterioration, create color changes, encourage the growth of mold and aerobic bacteria, and deplete nutritional value (Gaikwad et al. 2016).
- Using oxygen scavenging or absorbing agents ofers several benefts, such as inhibiting the formation of microbial growth, maintaining the quality of lipid-containing foods (preventing rancidity), avoiding discoloration, and avoiding oxidation (Johnson and Decker 2015; Nayik and Muzaffar 2014).
- Oxygen scavengers are widely used in this food industry, as they extend the shelf life of products from 3–4 to 14 days or more (Gaikwad and Lee 2017; Singh et al. 2016).
- Currently, commercial oxygen scavengers take many forms, including sachets, flms (directly in the package), and labels

Oxygen Scavenging Agents

- In principle, any oxidizing substrate, organic or inorganic, can be an oxygen scavenger (Sun 2016).
- In recent years, some novel nonmetallic agents have received considerable attention, including organic and polymer-based agents.
- Some potential oxygen scavenging agents for food packaging applications are listed and classified as in Table 1.

Table 1 Different types of oxygen scavenging agents

Classification	Oxygen scavenging agents	Oxidation mechanism
Metallic	Iron powder, activated iron, ferrous oxide, iron salt, Co (II), Zn	Oxidation of iron with supply of moisture and action of optional catalyst
Organic	Ascorbic acid, ascorbic acid salts, isoascorbic acid, tocopherol, hydroquinone, catechol, rongalit, sorbose, lignin, gallic acid, polyunsaturated fatty acids	Oxidation of organic substrate with metallic catalyst or alkaline substance
Inorganic	Sulfite, thiosulfate, dithionite, hydrogen sulfite, titanium dioxide	Oxidation of inorganic substrate by UV light
Polymer based	Oxidation–reduction resin, polymer metallic complex	Oxidation of polymer components with metallic catalyst (mostly cobalt)
Enzyme based	Glucose oxidase, laccase, ethanol oxidase	Immobilization

Ethylene Scavengers

- Ethylene, being a plant hormone greatly effects the ripening, softening, color change and sensory properties of fruits and vegetable commodities.
- To prolong shelf life and maintain an acceptable visual organoleptic quality, accumulation of ethylene in the packaging should be avoided.
- Ethylene scavengers are type of active packaging material that are used to scavenge ethylene from the packaging headspace of packaging.
- These ethylene capturing materials are usually used in the form of sachets that are placed inside the packaging, coating on packaging material or in form of ethylene scavenging active films.
- Ethylene can be absorbed or adsorbed by a number of substances including activated charcoal, molecular sieves of crystalline aluminosilicates, Kieselguhr, bentonite, Fuller's earth, brick dust, silica gel and aluminum oxide.

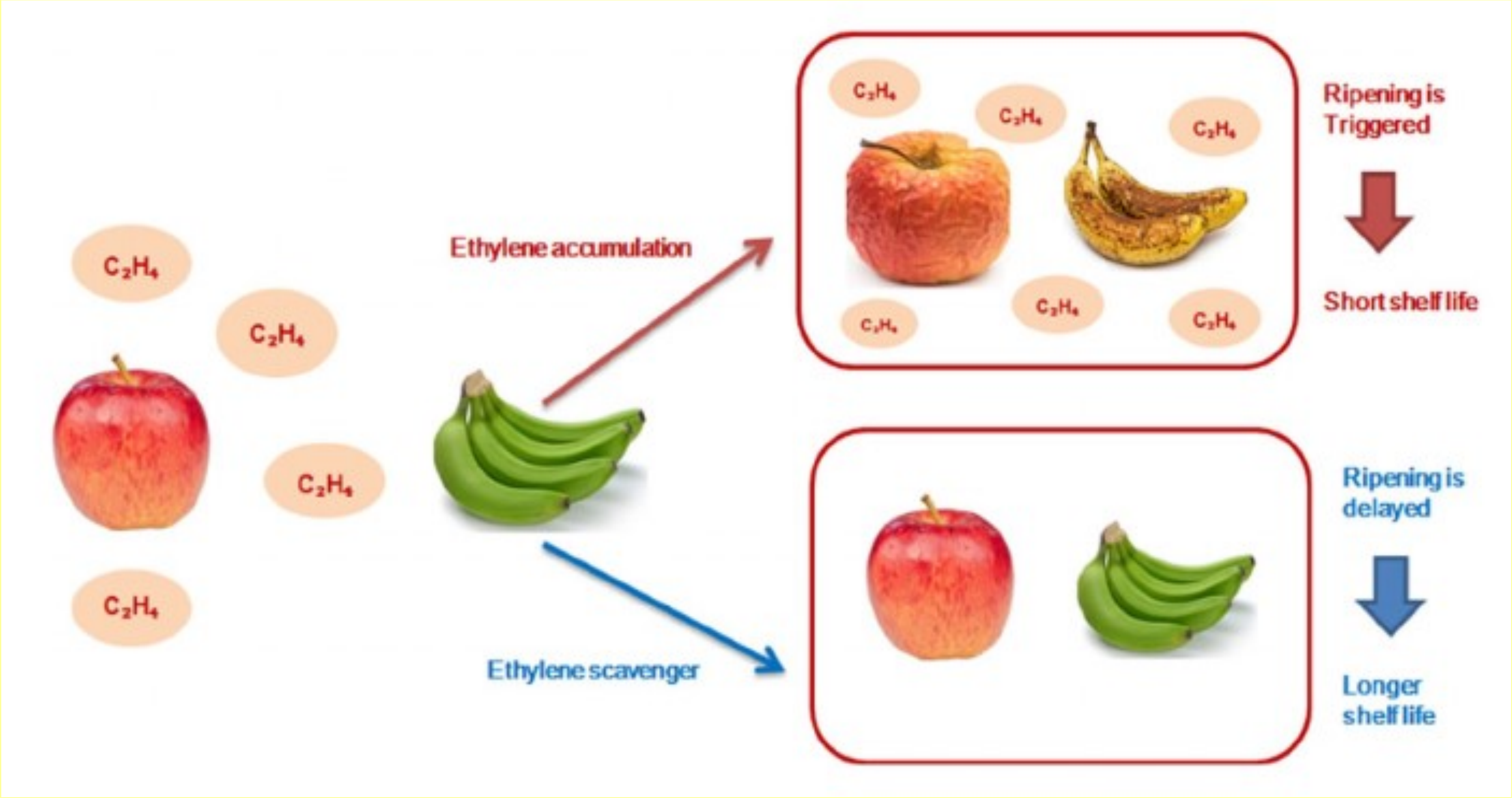
Ethylene Scavengers

- Ethylene scavengers can reduce the ethylene generation-rate by blocking the binding site.

- Based on their mechanism of action, ethylene scavengers can be classified as:
    1) Catalysts: Often based on platinum/alumina, these operate at elevated temperature (> 200ºc) and catalytically oxidise ethylene to carbon dioxide (CO2) and water.
    2) Stoichiometric oxidising agents: Mostly based on potassium permanganate (KMnO4), which again oxidizes ethylene and is itself reduced.
    3) Sorbents: These materials work by sorption of the ethylene and are often based on high surface area materials, including activated carbon, clays and zeolites. (Smith et al.,2009; Prasad & Kocchar, 2014)

- Potassium permanganate widely used ethylene absorber that oxidizes ethylene to ethanol and acetate via the breakdown of ethylene's double bond.

Ethylene scavenger is required to extend the shelf life of fresh produce as presented below



Oxygen Scavenging Technology

Iron-Based Systems

- Iron-based sachets are the type of oxygen scavenging system that has been used commercially for many years. It generally involves a reaction between iron powder contained in a permeable sachet that also may contain a desiccant. Iron powder reacts with oxygen using the following reactions :

$$Fe \rightarrow Fe^{2+} + 2e^{-}$$

$$\frac{1}{2}\,O_2 + H_2O + 2\,e^{-} \rightarrow 2\,OH^{-}$$

$$Fe^{2+} + 2\,OH^{-} \rightarrow Fe(OH)_2$$

$$Fe(OH)_2 + \frac{1}{4}\,O_2 + \frac{1}{2}\,H_2O \rightarrow Fe(OH)_3$$

Oxygen Scavenging Polymer Materials

- An effective oxygen scavenging polymer was developed in which dissolved reagents of known chemistry were incorporated into a polymer, and the trigger mechanism was light, which excited the reactive components in the film, thus, influencing oxygen diffusion into the polymer.
- The oxygen has to be in an excited singlet state, which requires the use of a photosensitizing dye and exposure to visible light. Another approach was based on transition-metal-catalyzed oxidation of an aromatic nylon. The transition metal in this case was cobalt or cobalt salt. This material eventually became known under the trade name, Oxbar.

Lecture – 3

- Ethylene scavenging technology
- Carbon dioxide and other scavengers
- Antimicrobial food packaging

Ethylene Scavenging Technology

- Removal of ethylene from the product environment by application of ethylene scavengers slows ripening and senescence, thereby enhancing quality and prolonging shelf-life.

Potassium Permanganate

- Ethylene scavenger systems involve either inclusion of a small sachet containing an appropriate scavenger in the packaging or incorporation of an ethylene absorber in the film structure.
- The most commonly used active component of the sachet is potassium permanganate (KMnO4) in order to oxidize/inactivate ethylene.
- However, KMnO4 is never used in direct food contact due to its high toxicity .

Minerals

- Another ethylene-scavenging system is based on the use of finely dispersed minerals, such as zeolite, active carbon, or pumice.
- These minerals could be incorporated into a plastic film structure commonly used in fresh produce packaging.
- Such minerals are intended to scavenge ethylene and also modify the gas permeability of the film so that carbon dioxide can diffuse faster and oxygen can enter more readily than through pure polyethylene to obtain an equilibrium.

Ethylene Scavenging Technology

- Metals and metal oxides are also good candidates for ethylene removal. Photoactive TiO2 is reported to oxidize ethylene into water and carbon dioxide. Since metal oxides are activated by either UV light, visible light or both, the negative effect of UV exposure on food quality should be considered.

Nanoparticles

- Nano-TiO2 is reported to oxidize ethylene into H2O and CO2.
- Yang and others (2010) tested PE blended with nano-powders of Ag, TiO2, and kaolin for preservation of fresh strawberries at 4 °C for 12 d. Results showed that active PE with nano-powders maintained physicochemical and physiological quality and sensory attributes of strawberry better than the control (PE).

Zeolite-based Minerals

- The most characteristic property of zeolites is their porous 3-dimensional structure with cation exchange, adsorption, and molecular sieving properties.
- Therefore, zeolites have been used in many industrial and agricultural applications, including as an ethylene-absorbing additive incorporated into packaging films.

Carbon Dioxide & other Scavengers

- Carbon dioxide (CO_2) is generally beneficial for food preservation and is thus often used as a flushing gas in modified atmosphere packaging (MAP).

- Relatively high CO_2 levels (60 to 80%) inhibit microbial growth on surfaces and in turn, prolong shelf life.

- The antimicrobial effect of CO_2 is related to its high solubility in foods, although the mechanism by which it inhibits microbial growth has not been clearly elucidated.

- CO_2 gas is readily soluble in aqueous and fatty foods, with a higher level of solubility at a lower temperature.

- Carbon Dioxide is known to suppress microbial activity.

- A CO_2 generator is only useful in certain applications such as fresh meat, poultry, fish and cheese packaging.

Ethanol Emitters

- Ethanol is used routinely in medical and pharmaceutical packaging applications, indicating its potential as a vapor phase inhibitor (Smith et al.,1987).
- It prevents microbial spoilage of intermediate moisture foods, cheeses, and bakery products.
- It also reduces the rate of staling and oxidative changes.
- Ethanol has been shown to extend the shelf life of bread, cake and pizza when sprayed onto product surfaces prior to packaging.

Moisture Absorbers

- Soaking up moisture by using various absorbers or desiccants is very effective in maintaining food quality and extending shelf life by inhibiting microbial growth and moisture related degradation of texture and flavor.
- For packaged dried food applications, desiccants such as silica gel, calcium oxide and activated clays and minerals are typically contained within tear-resistant permeable plastic sachets.
- For dual action purposes, these sachets may also contain activated carbon for odor adsorption or iron powder for oxygen scavenging (Rooney, 1995).

Antimicrobial Agents

- Antimicrobial food packaging materials have to extend the lag phase and reduce the growth rate of microorganisms in order to extend shelf life and to maintain product quality and safety.
- Alternatives to direct additives for minimizing the microbial load are canning, aseptic processing and MAP.
- Food packages can be made AM active by incorporation and immobilization of AM agents or by surface modification and surface coating.
- Antimicrobial films can be classified in 2 types:
  1) Those that contain an AM agent that migrates to the surface of the food, and
  2) Those that are effective against surface growth of microorganisms without migration

Temperature-controlled Packaging

- Temperature control active packaging includes the use of innovative insulating materials, self-heating and self cooling cans. For example, to guard against undue temperature abuse during storage and distribution of chilled foods, special insulating materials have been developed.
- Another approach for maintaining chilled temperatures is to increase the thermal mass of the food package so that it is capable of withstanding temperature rises.

Antimicrobial Food Packaging

- Antimicrobials in food packaging are used to enhance quality and safety by reducing surface contamination of processed food; they are not a substitute for good sanitation practices.
- Antimicrobials reduce the growth rate and maximum population of microorganisms (spoilage and pathogenic) by extending the lag phase of microbes or inactivating them.
- Antimicrobial agents may be incorporated directly into packaging materials for slow release to the food surface or may be used in vapour form.

Antimicrobial Agents used in Food Packaging

Silver ions

- Silver salts function on direct contact, but they migrate slowly and react preferentially with organics.
- Research on the use of silver nanoparticles as antimicrobials in food packaging is on-going, but at least 1 product has already emerged: FresherLongerTM storage containers allegedly contain silver nanoparticles infused into polypropylene base material for inhibition of growth of microorganisms.

Ethyl alcohol

- Ethyl alcohol adsorbed on silica or zeolite is emitted by evaporation and is somewhat effective but leaves a secondary odour.

Antimicrobial Food Packaging

Chlorine dioxide

- Chlorine dioxide is a gas that permeates through the packaged product. It is broadly effective against microorganisms but has adverse secondary effects such as darkening meat colour and bleaching green vegetables.

Nisin

- Nisin has been found to be most effective against lactic acid and Gram-positive bacteria. It acts by incorporating itself in the cytoplasmic membrane of target cells and works best in acidic conditions .

Organic acids

- Organic acids such as acetic, benzoic, lactic, tartaric, and propionic are used as preservative agents

Allylisothiocyanate

- Allylisothiocyanate, an active component in wasabi, mustard, and horseradish, is an effective broad spectrum antimicrobial and antimycotic.
- However, it has strong adverse secondary odour effects in food.

Metal oxides

- Nano-scale levels of metal oxides such as magnesium oxide and zinc oxide are being explored as antimicrobial materials for use in food packaging.

Lecture – 4

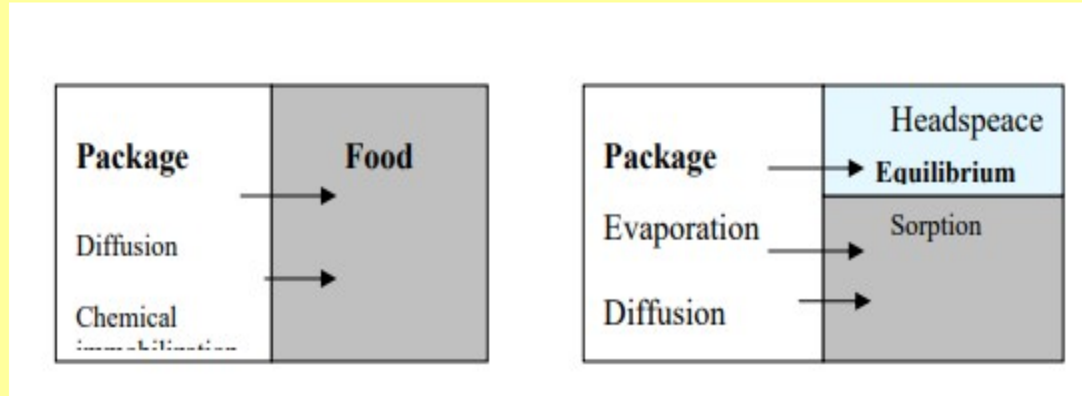
- Constructing an Antimicrobial Packaging System
- Factors Affecting the Effectiveness of Antimicrobial Packaging.

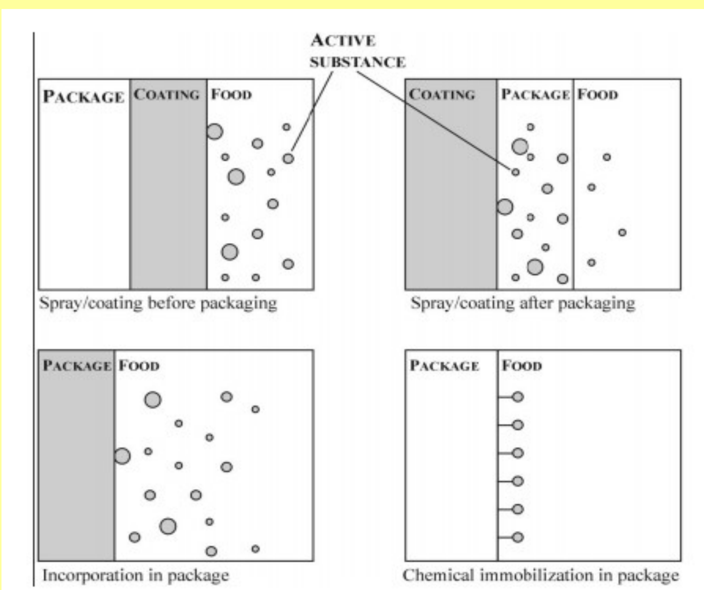
Constructing an Antimicrobial Packaging System

- Antimicrobial agents may be incorporated into the packaging materials initially and migrate into the food through diffusion and partitioning (Han, 2000).
- Package/headspace/food systems are represented by foods packed in flexible packages, cups, and cartons.
- Evaporation or equilibrated distribution of a substance among the headspace, packaging material and/or food has to be considered as a part of main migration mechanisms to estimate the interfacial distribution of the substance.
- Antimicrobial packaging can take several forms including:
  - Addition of sachets/pads containing volatile antimicrobial agents into packages.
  - Incorporation of volatile and non volatile antimicrobial agents directly into polymers.
  - Coating and adsorbing antimicrobials onto polymers surfaces.
  - Immobilization of antimicrobials to polymers by ion or covalent linkages.
  - Use of polymers that are inherently antimicrobial.
- Besides diffusion and equilibrated sorption, some antimicrobial packaging uses covalently immobilized antibiotics or fungicides, or active moieties such as amine groups.

Constructing an Antimicrobial Packaging System

- Most food packaging systems represent either a package/food system or a package/headspace/food system





- Figure besides shows the mass transfer phenomena of an active substance incorporated into a film or coating, with different applications.

Modeling of the Antimicrobial Film or Package

Several factors must be taken into account in the design or modeling of the antimicrobial film or package:

Chemical nature of films/coatings, casting process conditions and residual antimicrobial activity

The choice of the antimicrobial is often limited by the heat liability of the component during extrusion or by the incompatibility of the component with the packaging material. For example, 1% potassium sorbate in a LDPE film inhibited the growth of yeast on agar plates.

Characteristics of antimicrobial substances and foods

Food components significantly affect the effectiveness of the antimicrobial substances and their release. Physicochemical characteristics of food could alter the activity of antimicrobial substances. For example, the pH of food influences the ionization (dissociation/association) of most active chemicals, and could change the antimicrobial activity of organic acids and their salts.

Storage temperature

Storage temperature can affect the antimicrobial activity of chemical preservatives. Generally, increased storage temperature can accelerate the migration of the active agents in the film/coating layers, while refrigeration slows down the migration rate. The temperature conditions during production and distribution have to be predicted to determine their effect on the residual antimicrobial activity of the active compounds.

Mass transfer coefficients

The simplest system is the diffusional release of active substances from the package into the food. A multilayer design has the advantage that the antimicrobial can be added in one thin-layer and its migration and release controlled by the thickness of the film layer or coating. In practice, a matrix of several layers is used to control the rate of release of the active substance. Control of the release rates and migration amounts of antimicrobial substances from food packaging is very important.

Physical properties of packaging materials

When antimicrobial activity is added to packaging materials to reduce microbial growth, it may affect the general physical properties of the packaging materials. The performance of the packaging materials must be maintained after the addition of the active substances, even though the materials contain more heterogeneous formulations.

Factors Affecting the Effectiveness of Antimicrobial Packaging

- Physical and mechanical integrity of packaging materials is affected by the incorporated antimicrobial agents. If the antimicrobial agent is compatible with the packaging materials and does not interfere with the polymer-polymer interaction, a fair amount of the antimicrobial agent may be impregnated into the packaging material without any physical and mechanical integrity deterioration.
- However, the excess amount of antimicrobial agent that is not capable of being blended with packaging materials will decrease physical strength and mechanical integrity.
- Although there is no physical integrity damage observed after a low level of antimicrobial agent addition, optical properties can be changed by losing transparency or changing color of the packaging materials.
- Since the antimicrobial agent is contacting the food or migrating into food, the organoleptic property and toxicity of the antimicrobial agent should be satisfied to avoid quality deterioration and to maintain the safety of the packaged foods.
- The antimicrobial agents may possess strong taste or flavor, such as a bitter or sour taste as well as an undesirable aroma, that can affect the sensory quality adversely.

For any type of queries do mail your question on jnkvvstudents@gmail.com

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